Extending the Multimedia Patient Record across the Wide Area Network

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The Dept. of Veterans Affairs is developing and testing a wide area medical network with multimedia capabilities for coordination and consolidation of medical services across locations. The system is composed of multimedia information systems at individual medical centers connected by a high speed wide area network. The DHCP Imaging System, which has been in clinical use for six years, provides storage management and workstation acquisition and display of the multimedia data. Teleconsulting capability using a variety of mechanisms is being prototyped and tested to meet medical staffing and consultation needs.

OVERVIEW

To meet today's needs for coordinated care delivered at multiple sites by various clinicians, the VA's imaging system is being extended to operate across a nationwide wide area network (WAN). This paper will describe the system operating at individual medical centers, and the network and software support for data and process sharing across the wide area network.

The system has two core components which can be described as NODES and NETWORKS. The nodes are the collections of host systems at the individual medical centers, and the network is the related telecommunications systems and software connecting all of the host system nodes. For the purpose of this paper the network discussion includes the methodologies for accessing information from other nodes. In a sense, the nationwide capability is an expansion of the VA's successful experience in hospital-wide multimedia systems. The experience gained on those systems was invaluable to the creation of the nationwide capability.

MULTIMEDIA INFRASTRUCTURE AT EACH MEDICAL CENTER

Clinicians use many different kinds of medical data when treating patients. These include text, drawings, images such as xrays and endoscopic pictures, and graphics such as electrocardiograms. These constitute an important part of the medical record of the patient, but they are not normally stored in the patient's chart because of their awkward size or non-paper media. Rather, they are stored throughout hospitals by the various medical services that collected them [1]. Manual and computer-based medical records ordinarily do not contain multimedia data, leaving the physician to deal with a fragmented patient record widely scattered throughout the hospital [2].

To address this problem within medical centers, the Dept. of Veterans Affairs (VA) created an integrated electronic record that includes a variety of multimedia data linked with patient's online text records from pathology, radiology, medicine and surgery. The term multimedia is used here to refer to the incorporation of text and multimedia data (still images, audio data, or motion video) in an automated system to enhance the productivity of the user. Complete multimedia systems must provide multimedia data storage and handle any acquisition and display devices or processes required by each multimedia data type. The DHCP Imaging System began operation in 1990 with a multimedia infrastructure which handled text and still image data. It is now expanding to handle other types of multimedia data such as electrocardiogram signal data, scanned documents, audio and motion video.

0195—4210/96/$5.00

Multimedia data storage system

For up to six years, the DHCP Imaging System has been making multimedia data available to clinicians at several pilot VA medical centers. This unique distributed system manages medical images as an integral part of its HIS [3]. Imaging workstations located throughout the hospital capture and display a wide variety of medical images including cardiology studies, microscopic pathology slides, endoscopic examinations, radiology studies, in situ pathology as seen in the operating room, and images of dermatologic lesions. These are linked to the procedure reports in the HIS to provide image and text data in an integrated manner that facilitates the clinician's task of correlating that data and making patient care decisions in a timely and accurate way. The system aids communication and consultation among physicians -- whether in the same department, in different medical services, or at different sites.

Full-functioned hospital information system

The VA's DHCP hospital information system (HIS) is an integrated system based on a central set of software development tools. All of DHCP's many software modules, such as the laboratory, pharmacy, radiology, surgery, medicine, health summary, progress notes, problem list and discharge summary modules, are based on the VA toolkit and adhere to its rules. VA's internal system development provides compatibility and allows the VA to enhance its HIS to meet constantly changing requirements.

Client server workstation user interface

The DHCP Imaging System uses a local area network to connect imaging workstations to multiple magnetic and optical disk multimedia data servers and to the DHCP hospital information system. The HIS server supplies information about the multimedia objects. Workstation software accesses the file servers and provides the multimedia data display. All images and patient text data are available from any workstation in the medical center to users with security access.

The workstation meets clinicians' needs for true color image displays of up to 16 million colors per pixel; for display of 12-bit gray scale images; for digital image capture on the workstations; for display of other multimedia data such as motion video and electrocardiogram data; and for HIS data display.

The V.A. has adopted a new client server workstation architecture to allow its clinical workstations to communicate with its hospital information system. TCP/IP messages are used for communications between VA developed broker software located on the HIS and the workstations. All messages are processed by the broker software which performs the requested operations on the HIS and returns the results to the workstation via a TCP/IP message. DHCP security logon and server connection is also handled by the broker software. With the proper security privileges, a workstation user may connect to any HIS server on the wide area network. Workstations currently run Microsoft Windows. Software running on the workstations is written in Delphi, except for integrated off-the-shelf products.

System and device interfaces for data acquisition

An image capture workstation typically contains either a frame grabber card or a SCSI interface to a scanner or other input device. Images are generally collected by consulting services to meet their own needs in making study interpretations and preparing recommendations, as well as for the referring physicians.

The VA has interfaced commercial radiology picture archiving and communications systems (PACS) with its hospital information system using the ACR-NEMA standard. This interface is currently running at seven VA and DOD medical centers [4]. It is being upgraded to DICOM version 3. Further efforts are underway to implement the new DICOM Modality Worklist interface to directly transfer digital images from acquisition devices such as CT and MRI scanners and computed radiography systems.

NETWORK AND SOFTWARE CONNECTING MEDICAL CENTERS

The VA is now organizing patient care subnetworks across the country and is beginning consolidation of services across facilities within the subnetworks. The multimedia systems developed for individual medical centers are well positioned to support this consolidation and concomitant distance collaboration of clinicians. Because of consolidations of VA medical centers and increasing need for coordination of care at multiple locations and for resource sharing through teleconsultation, the VA is now extending its local area network based system to allow the sharing of multimedia data among medical centers on its wide area network.

To connect over 600 major facilities, the VA has installed a wide area packet-switched network known as the Integrated Data Communications Utility

(IDCU). It consists of a vendor-supplied 23,000 mile fully digital fiber optic network with four backbone nodes and twenty-two tributary nodes. It provides flexible redundancy and system management services. The IDCU wide area network (WAN) supports a number of protocols. Frame relay and supplemental T1 communications lines connect a large number of V.A. medical centers at rates up to 1.544 megabits per second. All other centers are connected with 56kb lines.

Models and mechanisms for multimedia data exchange

Several models which can be used to communicate patient data between facilities:

- o "Data push" model: Data can be moved by the originating or referring site. The originating site sends the essential set of data for the consultation; the recipient does not need to stand by during the time required for the transfer; and the data may be easily stored at the receiving side.
- o "Data pull" model: On the other hand, data can be moved by the consulting site. This model has the advantages of allowing the consultant to select the data required interactively; and the receiving site can verify whether all data was received and retransmit if necessary.
- o "Data Prefetch" model: This is a hybrid model where data is pushed or pulled ahead of the need and is stored at the consulting site until the time of the consultation. This model is normally used to avoid the clinician having to wait for the data to arrive.

Using these models, several mechanisms for multimedia data exchange have been prototyped by the VA, including:

- o direct transmission of images and associated medical record text
- o security sign-on to remote systems from multimedia workstations
- o use of DICOM messaging
- o use of electronic mail for multimedia messages

(1) Direct Transmission of Multimedia Data and Associated Medical Record Text

A feature of the VA's image acquisition software is that it allows transmission of collected images to a remote site for teleconsultation. The user enters the consultation request including patient identification, provider identification and contact information, reason for consultation, image information, and notes to the consultant. The software connects directly to the HIS at the remote consulting site. After user privileges are checked, the patient is looked up in the database and the user has the opportunity to register the patient if he or she is not found. Next the textual information is entered into the remote HIS. The images are transmitted in the background from the referring site, and an electronic mail message is sent to notify the consultants that a consultation is waiting.

This mechanism uses the push model. It has the advantages that the consultation becomes part of the patient's online record at both the referring and consulting sites. The consultant is does not need to be notified of the consultation until the data is available onsite. Data transmission occurs in the background, so line speed is not as critical as when a user is waiting.

(2) Security Workstation Signon across Network

Using a standard workstation, it is possible to connect to a remote system on the WAN and view a patient's medical record and multimedia data from a distant location, as long as the user has proper security privileges. No software modifications are necessary. This allows the extension of existing local imaging networks to produce more widely distributed imaging systems. This mechanism uses the data pull model; the user selects the data to be viewed interactively and the data is pulled by the workstation for display.

(3) Use of DICOM Messaging

Images and textual information may also be exchanged using DICOM standard messages. This mechanism is being used for radiology information communication at consolidated V.A. Medical Centers in the Baltimore area. Messages are sent over a T1 line from the Baltimore VA Medical Center HIS to the Perry Point VAMC, about 40 miles away, where a computed radiography system is located. For each radiology order, three messages are sent; the receiving interface uses the information to provide worklist information to a Computed Radiology xray acquisition device [5]. DICOM has the advantages that it is a standard that handles both textual and image data, including 8-16 bit gray scale images. Its object-oriented nature handles the patient-study-exam hierarchy very well. It allows DICOM components, such as image acquisition devices, data storage devices, or workstations, to be located remotely. DICOM's security provisions are limited, but this may change in the future.

(4) Internet Multimedia-mail Prototype

Prototype testing has been done to examine the use of Internet to support medical consultation. Multimedia mail containing medical textual information and images or other multimedia information can be accessed from http servers built into the VA's hospital information system environment. This mechanism uses a combination of data push and pull. The sender may cause the multimedia data to be moved to another server; the reader ultimately brings it to his workstation where it may be cached for rapid redisplay. However, there are privacy issues related to local caching where an individual can then redistribute private medical information.

Internet use offers many advantages including access from any location at any time to data at any other Internet location, ease of use, built-in capabilities such as protocol for gradual transmission and display, ability to add customized viewer software, and standards allowing ability to write http server and display software in different languages and hardware platforms. These advantages are offset by privacy and security concerns. Many of these can be lessened through the use of firewalls, restricted internal networks, password protection, and encryption. However, these protections reduce the advantages of this approach.

ISSUES IN MULTIMEDIA INFORMATION EXCHANGE

Several issues are important for teleconsultation. The first is the correct and identical identification of the patient at both sites. In many cases, the patient will not yet be known to the HIS patient registry at the consulting site. It must first be determined that the patient is not already registered, then the patient may be registered as a new patient. This allows the linking of patient information at each site and between sites. Patient registration is performed following an automated search for candidate matching patients and human verification that no match is present.

Next, when performing a teleconsultation, the clinician does not have the same benefits of patient contact that an onsite clinician has. To avoid further loss of information, consultation from a distant location requires at least the same complete integrated patient record available to onsite physicians. Both images and associated text must be transmitted and their association must be maintained. Commercial teleconsulting systems typically are unable to provide this. The VA's client/server workstation architecture allows direct communication with HIS's at multiple sites. The VA's software infrastructure includes integration structures at each medical center to support this capability.

Another important issue is the time and resources required to transmit images which are particularly large files. The time may be prohibitive, however it may be possible to compress the data without significant loss before transmission. A number of commercial systems use image compression, with or without irreversible loss of data. The quality of data required seems to vary by specialty and many specialties have not performed studies to determine the image quality required. The issue may be further obscured because the necessary image quality will vary with the types of abnormalities being distinguished.

Finally, privacy and security of patient data is critical. The act of transmission can increase the risk of privacy invasion or corruption of data. In addition, the data may be stored at two sites rather than one following the consultation. Clinicians at both sites may have a continuing "need to know" about a particular patient's data at least for the time period of the care episode.

TELECONSULTING EXPERIENCE

The DHCP Imaging System's first teleconsulting test system was a telemedicine standalone component installed by the Indian Health Service in Alaska for orthopedic telemedicine. Xrays were digitized at a remote site and transmitted along with patient information to the consulting facility. Over the first two months of operation, four medical evacuations were avoided, at substantial cost savings. The cost of the system is approximately one quarter that of a commercial system. The service was popular, and other specialties experimented with the telemedicine capability. Text data was made available to consultants, but was not integrated with the patient's online IHS medical record; this step is currently underway.

An integrated telemedicine capability was tested at two V.A. Medical Centers. Images were scanned at the remote site, at diagnostic resolution (2k x 2k x 12-bit). They were transmitted directly to the consulting site over the V.A.'s frame relay lines and stored on the file server. The patient was registered in the hospital information system at the consulting

site, if not already known to the system. Data related to the consultation was linked to the images and made available as part of the online patient record.

The V.A. has consolidated a number of medical centers at various locations across the country. Three of these sites are in the Baltimore area. All three sites share the same hospital information system. The largest site has an installed filmless radiology system provided by a commercial vendor. This PACS system is linked to the hospital information system using an ACR-NEMA standard interface. The remote sites have computed radiography systems with DICOM interfaces that receive worklist information from the hospital information system via DICOM messages. They can communicate images over a T1 link to the PACS system for reading. The PACS system then communicates the images to the hospital information imaging system via the ACR-NEMA interface, making the images available on workstations. At the present time, patient's images and text reports can be viewed by connecting a workstation across the wide area network to DHCP and image servers. In the near future, images will also be stored on DICOM storage devices locally at the remote sites for a short period of time for more rapid viewing on local workstations.

CONCLUSIONS

The VA has developed an infrastructure to support the multimedia patient record consisting of the following components:

- Multimedia data storage system (DHCP Imaging System)
- Full-functioned hospital information system (DHCP)
- Workstation user interface based on client/server tools
- System and device interfaces for data acquisition
- High-speed wide area network linking VA locations

This infrastructure has supported multimedia patient records at several individual VA medical centers over the past six years, with over 900,000 medical images collected at these sites. The experience gained on those systems was invaluable to the creation of the nationwide WAN.

The three models for multimedia data transfer have a place in the repertoire of teleconsulting applications. The data push model should be used to conserve consultant time at the receiving site or when communications lines are slow. The data pull model should be used when user interaction in the selection of data to be viewed is important. As consultation takes place in additional locations such as the clinician's home or is shared by pools of individuals on the network, it will be even more important to be able to match the model and mechanism to the user needs of the situation.

It is extremely important to correctly identify the patient across sites. Otherwise, the HIS at each site will be filled with duplicate patient entries. Network user directory servers will also be necessary to validate system users' access privileges at multiple sites on the network, to verify providers' privileges, and to track consultations sent to a pool of consultants on the network.

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Acknowledgments

The authors thank the staff of the Medical Center test sites, including Baltimore, Milwaukee, Iron Mountain, Anchorage, and Bethel. We also thank Steve Pollock at the Kansas City V.A.M.C. for his work on the initial Internet prototype software.